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Research Paper

Amino acid racemization in lacustrine ostracodes, part II: Paleothermometry in Pleistocene sediments at Summer Lake, Oregon

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ABSTRACT

The extent of amino acid racemization in fossil ostracodes of known age has served as a valuable proxy indicator of Pleistocene temperatures in the Great Basin of the western U.S. Here we assess the utility of this technique for estimating paleotemperatures in the Summer Lake basin of south-central Oregon. The enantiomeric composition (*D*/*L* values) of aspartic acid and glutamic acid was measured in *Candona* and *Limnocythere* ostracode valves collected from 32 sedimentary horizons within a ~16-m section of lacustrine sediments associated with pluvial Lake Chewaucan and exposed along the Ana River. Independent geochronologic control spanning the past 250,000 years is provided by a recently revised age-depth model for the Ana River section. Measured *D*/*L* values in the fossil ostracodes generally increase down-section, but the trend is not monotonic and contains stratigraphic reversals. The *D*/*L* values from the Ana River section are significantly lower than those measured in ostracodes of comparable age from Lake Bonneville sediments, implying that the Summer Lake basin was colder than the Bonneville basin during the middle and late Quaternary. Although a higher north-south temperature gradient during the Pleistocene is expected considering the proximity of the Ana River site to former ice sheets, published amino acid paleothermometry equations for *Candona* yield unreasonably cold Pleistocene temperatures at Summer Lake. Measurements of fossil *Candona* valves from deposits across the western U.S. and northern Sonora reveal abnormally high amino acid concentrations in the subset of Ana River ostracodes analyzed, possibly related to unusual preservation and environmental factors at this site. This suggests that ostracode preservation has an influence on rates of racemization which complicates the application of amino acid paleothermometry at the Ana River site.

1. Introduction

During the Quaternary Period, the Great Basin of the western U.S. contained as many as 80 documented pluvial lakes which expanded and contracted on centennial to millennial time scales in response to climate perturbations (e.g., Mifflin and Wheat, 1979; Smith and Street-Perrott, 1983; Negrini, 2002). Lacustrine sediments and shoreline features in these pluvial lake basins preserve detailed records of regional paleoclimate (Oviatt, 1997; Benson, 1999). However, considerable ambiguities remain over the relative degrees to which past lake fluctuations were driven by temperature controls versus precipitation and other forcings (e.g., Antevs, 1952; Menking et al., 2004). Efforts to characterize the importance of specific climatic elements in the hydrologic budget of pluvial lake systems are hindered by the paucity of quantitative Quaternary temperature estimates in the western U.S., particularly for intervals prior to the Last Glacial Maximum (LGM, ~26.5 to 19.0 ka; Clark et al., 2009). Although a number of paleoenvironmental proxies derived from lacustrine sediments are indicative of past temperatures, these proxies can also be affected by biological processes, lake chemistry, and precipitation patterns, thus making it difficult to uniquely distinguish temperature signals (Palacios-Fest et al., 1993; Cohen et al., 2000). Likewise, most other paleoclimate proxies commonly developed in terrestrial settings, such as reconstructed changes in glacier equilibrium-line altitudes (e.g., Leonard, 1989; Laabs et al., 2006; Marcott et al., 2009), are not exclusively dependent on temperature.

Amino acid paleothermometry is one of the few techniques capable of resolving past temperatures in isolation from other paleoclimatic influences (e.g., McCoy, 1987; Oches et al., 1996; Kaufman, 2003a). Amino acids exist as mirror-image enantiomers with identical chemical properties. Most living organisms utilize only L-form (*levo*) enantiomers, and upon death the diagenetic process of racemization inverts these to D-form (*dextro*) enantiomers.

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The extent of amino acid racemization in fossilized remains, measured as D/L, is dependent on both time elapsed since death and ambient temperature (Miller and Clarke, 2007). Because the temperature sensitivity of the racemization reaction can be described by the Arrhenius equation, D/L values may be used either to date samples which have experienced a well-defined burial temperature, or conversely to reconstruct the thermal history of a site if sample ages are independently known.

Here we assess the utility of amino acid paleothermometry for inferring middle to late Pleistocene temperatures in the pluvial Lake Chewaucan basin of south-central Oregon (Fig. 1). Our analyses follow procedures developed by Kaufman and Manley (1998) and modified by Kaufman (2000), which enable D/L measurements in sub-milligram quantities of microfossils. The temperature dependency of amino acid racemization was established by Kaufman (2000) for modern and fossil ostracodes, allowing paleotemperatures to be determined. Capitalizing on these improved analytical capabilities and thermal calibrations, Kaufman (2003a) used the extent of amino acid racemization in lacustrine ostracode fossils to calculate Quaternary temperatures in the Lake Bonneville basin of Utah. Because of their broad environmental tolerance and nearly ubiquitous preservation in carbonate-rich lacustrine sediments (e.g., Delorme, 1969), racemization in ostracode fossils is a potentially powerful tool for reconstructing past thermal conditions in pluvial lake basins across the Great Basin.

2. Study location and previous work

2.1. Site setting

The site of this investigation is an exposed bluff along the Ana River, the only major waterway flowing into Summer Lake, south-central Oregon (Figs. 1, 2). Modern-day Summer Lake occupies the largest of four sub-basins that once held the coalesced pluvial Lake Chewaucan (Russell, 1884; Allison, 1940, 1982; Licciardi, 2001; Zic et al., 2002). The modern climate of the Summer Lake basin is

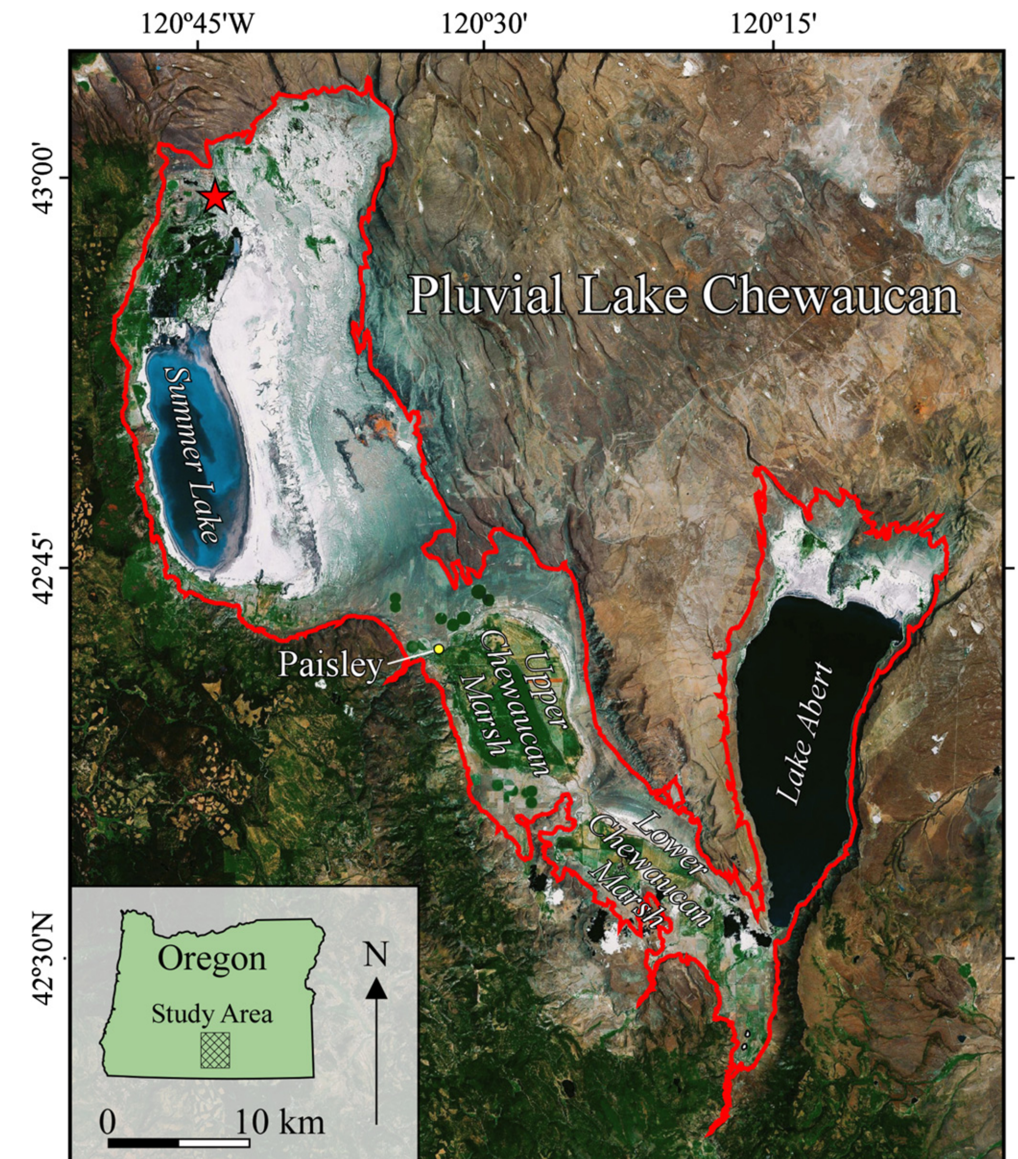

Fig. 1. Satellite image of pluvial Lake Chewaucan. The Lake Chewaucan basin is divided into four sub-basins occupied by modern Summer Lake, Upper Chewaucan Marsh, Lower Chewaucan Marsh, and Lake Abert. Red line shows maximum late Pleistocene extent of pluvial Lake Chewaucan. Red star marks location of the Ana River section. Satellite image base from Google Maps. Modified from Licciardi (2001). (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article).